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Technical Lesson 62

VACUUM TUBE TRANSMITTERS

Before considering the different types of commercial tube transmitters it is advisable to mention a few of the requirements in regard to the generation of radio power for the purpose of setting an antenna system into excitation. This is, of course, essential in order that an alternating electric field be produced in the space surrounding the antenna. It is this generated radio power that makes possible the transmission of voice, music or telegraphic messages through space.

The transmission of voice or music, more familiarly known as "Broadcasting", will be dealt with in a subsequent lesson. In this lesson we will confine our subject to commercial telegraph transmitters. It is known that radio power takes the form of a very high-frequency alternating current which traverses the antenna system. This current, having a frequency in the order of hundreds of thousands to millions of cycles per second, is introduced into the coils (inductances) and other elements which comprise the antenna in the manner which we will explain further on in our lesson. These inductances, (and loading inductances if used,) are inserted in the antenna circuit between the aerial and the ground. Sometimes a counterpoise is used in addition to a regular earth ground. However, for shipboard installation a counterpoise is unnecessary, for a good ground connection can most generally be found.

One or more vacuum tubes are required to produce this high-frequency current which must flow through the wires and apparatus comprising the entire antenna circuit as we have just mentioned. These tubes are known as "oscillators". Additional tubes and their associated circuits are generally used in modern equipment to build up the power of the oscillator circuit's output in order that a high-frequency current of sufficient magnitude will set up a very strong electric field around the aerial. Vacuum tubes used for this purpose of stepping-up the oscillator's output are called "power-amplifiers". Hence, by arranging a suitable oscillator circuit, and coupling it to a power amplifier, the latter then can be arranged to feed its output directly into the antenna, this being done usually through a coupling transformer in the commercial type transmitter. Hence, we are aware that the high-frequency current in the antenna of a transmitter is necessary to establish communication with a distant receiving station. It is obvious that without this current in the antenna system radiation of electromagnetic waves could not take place. An operator on duty frequently looks at the radiation ammeter in order to be certain that his signals are going out in the air.

The vacuum tube or tubes which determines the frequency of the radiated wave is the oscillator, as we previously stated. We more often refer to a tube performing this function as a "master oscillator". It is also called an "exciter" in some transmitters, but it should be remembered that all of the names mean one and the same thing. Then, it can be said that the oscillator

circuit is the frequency-determining part of the transmitter.

Commercial tube transmitters used for telegraphy are provided with a suitable switching arrangement and adjustments to enable the operator to quickly select any one of several wavelengths. By means of the switches and tapped arrangement the constants of the tuned circuits can be quickly altered by throwing a switch, and a simple adjustment or two to place the circuits in resonance at any of the wavelengths provided. By "constants" we mean that the inductance and capacity, or both, of the tuned circuits are changed, and wavelengths which are known from previous calibration may be selected. The process of varying the number of turns used on a coil or changing the capacity of a condenser for the purpose of obtaining a definite frequency from the master oscillator is called "tuning." The adjustments we referred to are for the purpose of providing fine tuning for the set when working on a particular wavelength. This is done as a rule with each change of wavelength when working other ships.

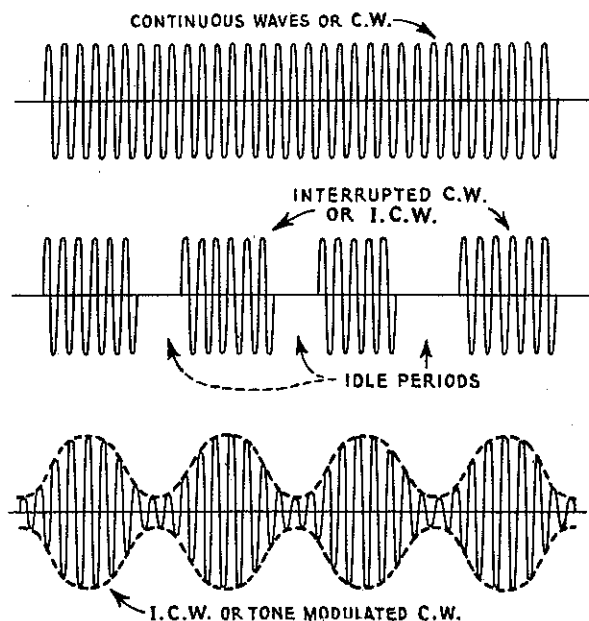


Figure 1

Let us now consider the different methods by which an oscillator tube and its associated circuits consisting of inductance and capacitance (that is, coils and condensers) may be arranged in order to provide the requisite alternating current for antenna excitation. The three well-known oscillator circuits are the Colpitts, the Hartley, and the Meissner. Regardless of what type oscillator circuit is employed in a transmitter the ultimate result will be the same, that is, a radio frequency current of a definite frequency will circulate through the oscillator system. We may call this high-frequency current an "oscillating current" or simply "oscillations".

The upper curve in Figure 1 shows the uniformity with which the oscillations are produced. Observe that each cycle occurs in the same time - called "time period" and the peaks or amplitude heights of all the oscillations are equal. It is because of these characteristics that this energy is known as a continuous al-

ternating current of constant amplitude. When such energy is utilized to deliver power to an antenna system it causes a continuous wave (abbreviated C.W.) to be propagated or radiated away from the antenna through space. The middle wave is known as an interrupted continuous wave (or I.C.W.). It is to be noted that the oscillations are generated and then discontinued for short intervals, which effect is produced by the use of a chopper. Each group of oscillations will cause one click in the diaphragms in the headset of the operator at the distant receiving station. So, if one thousand groups of such oscillations are sent out every second while the dots and dashes of the code are formed, then one thousand deflections of the diaphragms will result and a note having a musical pitch will be heard. The lowest curve shows how a C.W. output of an oscillator can be modulated, which means that the amplitudes of the oscillations are f

to undergo a continual variation by super-imposing an audio-frequency current upon the continuous oscillations. We will explain in one of the transmitters how an audio-oscillator circuit is coupled into the oscillator and power amplifier circuit to provide this periodic rise and fall in the amplitudes as shown by the lowest curve. If these periods, which we may call the "modulation frequency", occur in the audio range from about 600 to 1000 per second the received signal will have a musical tone and somewhat the characteristics of an I.C.W. signal. And so in commercial operating we frequently call a modulated C.W. signal I.C.W. whereas it could also be called tone modulated C.W.

We are now interested in the three conventional type oscillator circuits which we have made mention of.

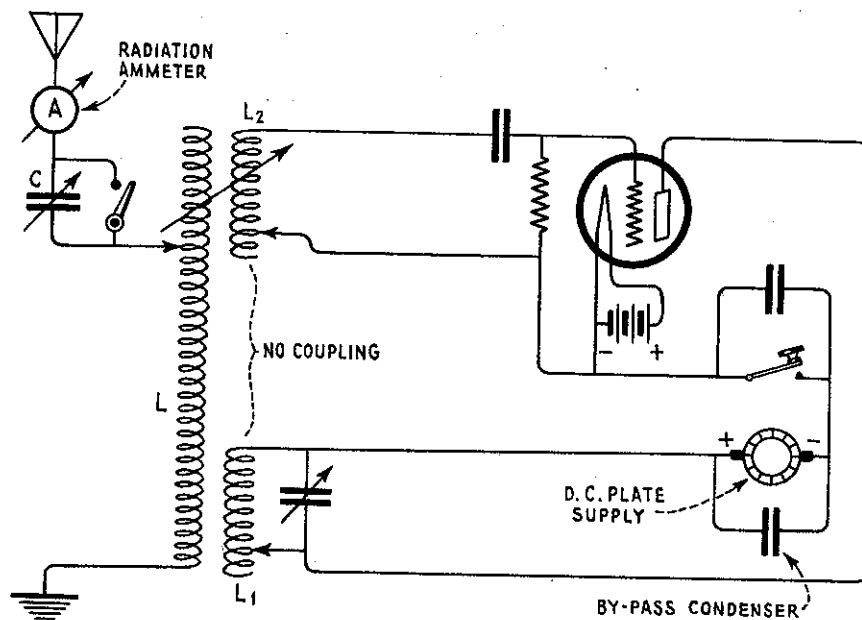


Figure 2

Meissner Oscillator. The fundamental Meissner oscillator circuit is shown in Figure 2. This circuit embodies inductances of suitable size for the purpose of feeding back power from the plate to grid, and condensers to control the frequency at which the continuous oscillations are generated.

Note that plate coil L_1 and grid coil L_2 are magnetically coupled to L as shown, whereas no coupling exists between L_1 and L_2 . The oscillatory circuit is not part of the tube circuit. The Meissner circuit provides a very flexible arrangement because maximum radio power may be transferred from the tube circuit to the load circuit, that is, the oscillatory circuit. The latter circuit may actually represent the antenna system as we have shown in the diagram and here the capacity is the antenna distributed capacitance in addition to any condenser which may be included for the purposes of tuning.

The feed-back adjustment may be accomplished by simply varying the coupling between the various inductances and does not require adjustments of the tube circuit proper as would be the case in either the Hartley or Colpitts oscillator circuits. Adjustable coupling is indicated by the arrow.

The action of the circuit follows: The plate current rising and falling in value through coil L1 at a high frequency sets up an alternating magnetic field surrounding itself. The rapidly changing flux threads through the upper turns of L inducing therein an alternating e.m.f. Consequently an alternating current of similar frequency to that of the plate current variations will flow through the oscillatory circuit. The variations in flux around the lower turns of L induces an alternating e.m.f. across coil L2. The grid receives this induced voltage and in turn causes the plate current to increase and decrease in strength thus producing pulsations of current again through L1. The feed-back is from L1 to L and from L to L2. The circuit L C is like a link circuit, its frequency being regulated by changes in the variable condenser C. The rise and fall values of the plate current, that is, the alternating component, passes through the by-pass condenser.

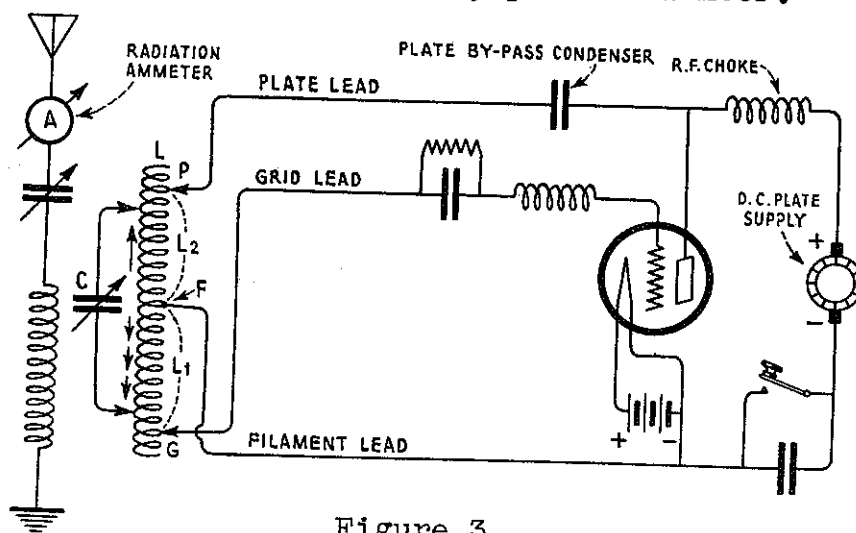


Figure 3

Hartley Oscillator. The Hartley oscillator circuit shown in Figure 3 consists of a single inductance L connected between grid and plate of the tube, while a tap taken from a point near the middle portion of the coil is attached to the filament. The oscillatory circuit consists of all of the turns in L and variable condenser C. The circuit is known as a direct or conductively coupled circuit because grid coil L1 and plate coil L2 are electrically connected at F, the winding being continuous from G to P.

Alternating voltage changes impressed upon the grid will be magnified or amplified in the tube's output or plate circuit, and providing this amplification is sufficient to overcome all the effect of damping, the tube and the circuit will become a generator of radio-frequency oscillations. The damping is the dissipation of energy in the circuit due to resistance, etc. The alternating voltage referred to is produced by the alternating component (i.e., the rise and fall values) of the plate current as it flows through plate coil L2. The long arrow marked P indicates the direction of current flow through the plate circuit and the short arrows marked G the direction of the grid current. We are only interested in the direction of the current flow through L1 and L2, and the effect of the self-inductance of L2 upon L1 in producing an alternating voltage across L1.

First, let us bear in mind that the total current flowing in the plate circuit of a tube when oscillating is a pulsating direct current, which consists of an alternating component and a direct component. The alternating component is represented by the rise and fall or alternations of the direct current as we have heretofore stated, and it flows through the plate by-pass condenser. However, the d-c component flows through the r-f. choke coil and thence to the d-c. generator circuit. It is the a-c. part or component of the plate current that is utilized in setting up a changing magnetic field in L2 causing an alternating voltage to be induced across the coil's winding, or between P and F. Since coil L1 is connected to L2 at F the alternating voltage will cause an alternating current to flow through oscillatory circuit L C. Notice that inductance L is really an auto-transformer because this winding forms both the plate and grid turns.

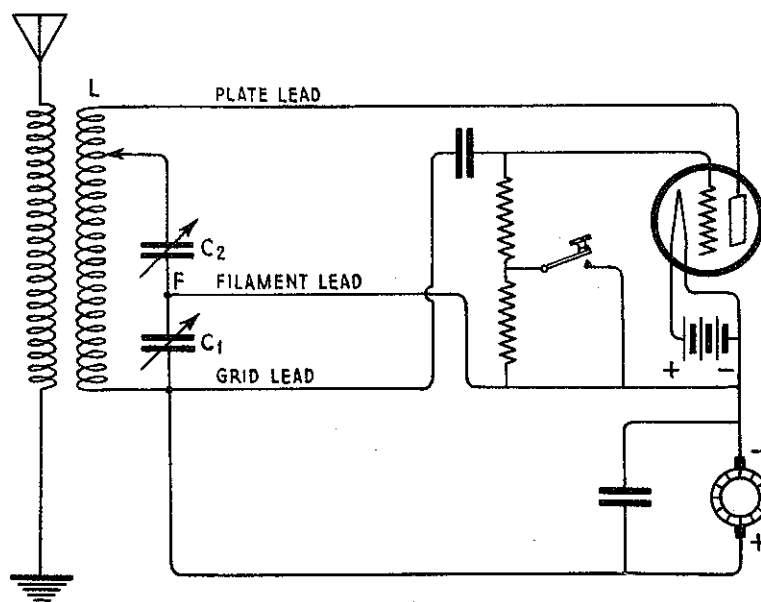


Figure 4

The oscillating current circulating through L C causes an alternating voltage to be set up across coil L1, or between points G and F. Since the grid is connected to one side of L, as shown in the diagram, the grid must receive this induced e.m.f. Thus the charged grid exercises its usual influence in controlling the electron stream reaching the plate, or the plate current, which is the same thing. We may then sum up this action in a few words by saying that the plate coil supplies the requisite alternating e.m.f. to reinforce the oscillations, and the coupling between L1 and L2 furnishes the alternating voltage to the grid. Note particularly that in the Hartley circuit the grid excitation voltage is obtained from across a portion of the inductance.

This relation of the plate and grid circuits with regard to the direction of the respective currents is a very important factor in the tubes operation and we make mention of it here because it is well known that in all oscillator actions the plate circuit must furnish energy to the grid in such a way that the current flowing to the grid must excite the grid to a higher potential to cause the necessary change in plate current in order to make the action a retroactive one. This simply means that any change in conditions of the tube

circuits which might cause a variation either in plate current or grid current, regardless of how small, will increase in amplitude due to the feed-back, and progressive amplification of the oscillations will result.

Colpitts Oscillator. The difference between the Colpitts circuit and other types previously explained is mainly in the method utilized for obtaining the requisite grid alternating voltage. Observe in the diagram in Figure 4 how condenser C1 is connected between grid and filament and how the filament lead F is attached to the center of the total capacity of the oscillatory circuit. This circuit consists of capacities C1 C2 and inductance L. Thus in this type of oscillatory circuit it is necessary to employ two condensers connected in series and these in turn must be connected across the total inductance, or L, with the filament lead joined to the center of the condensers. The diagram clearly shows how this is done.

The alternating component of the plate current, as it passes through L sets up an oscillating current in circuit C1, C2 and L. An alternating voltage (or voltage drop) is thus obtained from across the terminals of condenser C1 and this voltage is applied directly between grid and filament. How this voltage is obtained and also how it is applied between these electrodes should be quite obvious for it is seen that C1 is connected to grid and filament. Thus, we learn that the feed-back voltage is obtained from the electrostatic charge in C1 when an oscillatory current circulates through the circuit. For this reason the Colpitts type is referred to as "capacity feed-back" and, since condenser C1 is used to excite the grid, this condenser is generally known as the "grid input condenser" or the "grid excitation condenser".

The principal difference, then, between the Hartley, or inductively coupled type, and the Colpitts, or capacitive coupled type, may be stated briefly as follows: The requisite grid excitation voltage or feed-back e.m.f. in the Hartley circuit is obtained from the voltage changes (called drop in voltage) across an inductance, the inductance being the grid coil between grid and filament. In the Colpitts oscillator the grid excitation voltage is derived from the voltage drop or e.m.f. generated across part of the capacity in the oscillatory circuit, the capacity being the grid input condenser connected between grid and filament.

Bear in mind, however, that in either system the essential changes in grid voltage are properly obtained and applied for maintaining the tube and its associated circuits in a state capable of producing continuous oscillations.

E.T. 3626-B 750 Watt Transmitter for CW and ICW Telegraph Service. This transmitter utilizes eight vacuum tubes of the UV-211, fifty watt type, one functioning as the master oscillator, one as an audio oscillator to provide for ICW transmission, and the other six as radio power-amplifiers. When used on the average ship antenna the transmitter covers a continuous range from 600 to 2500 meters, or 500 to 120 kilocycles. CW and ICW telegraphy are obtained by turning the signal switch on the panel to the proper position. The front panel view is shown in Figure 5 with all controls and meters identified. A side view of the transmitter is shown in Figure 6. The schematic circuit diagram showing the fundamental arrangement in the E.T. 3626-B transmitter is shown in Figure 7. The diagram shows only one set of Master oscillator (exciter)

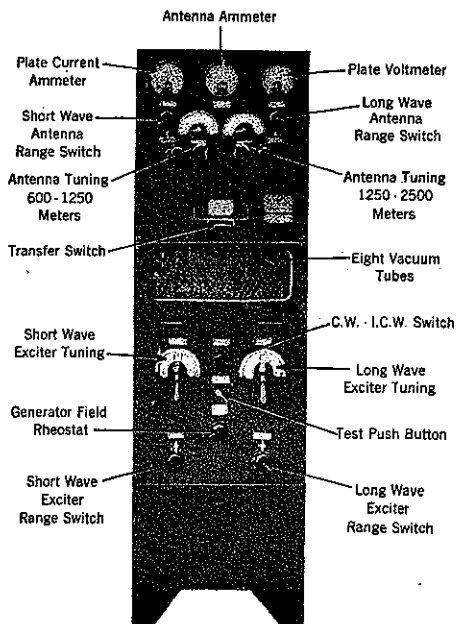


Figure 5

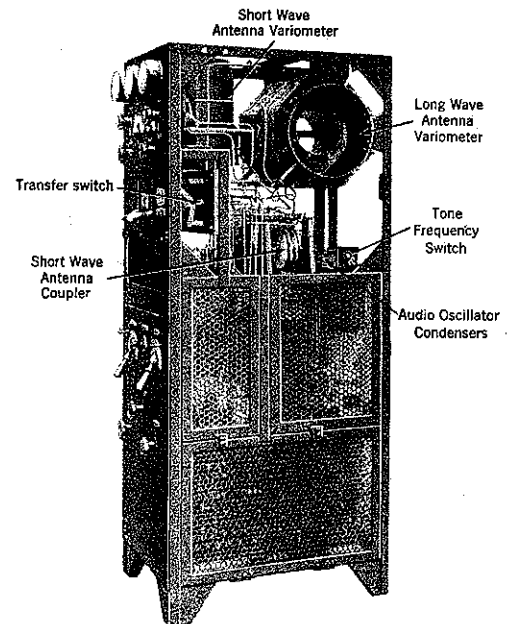


Figure 6

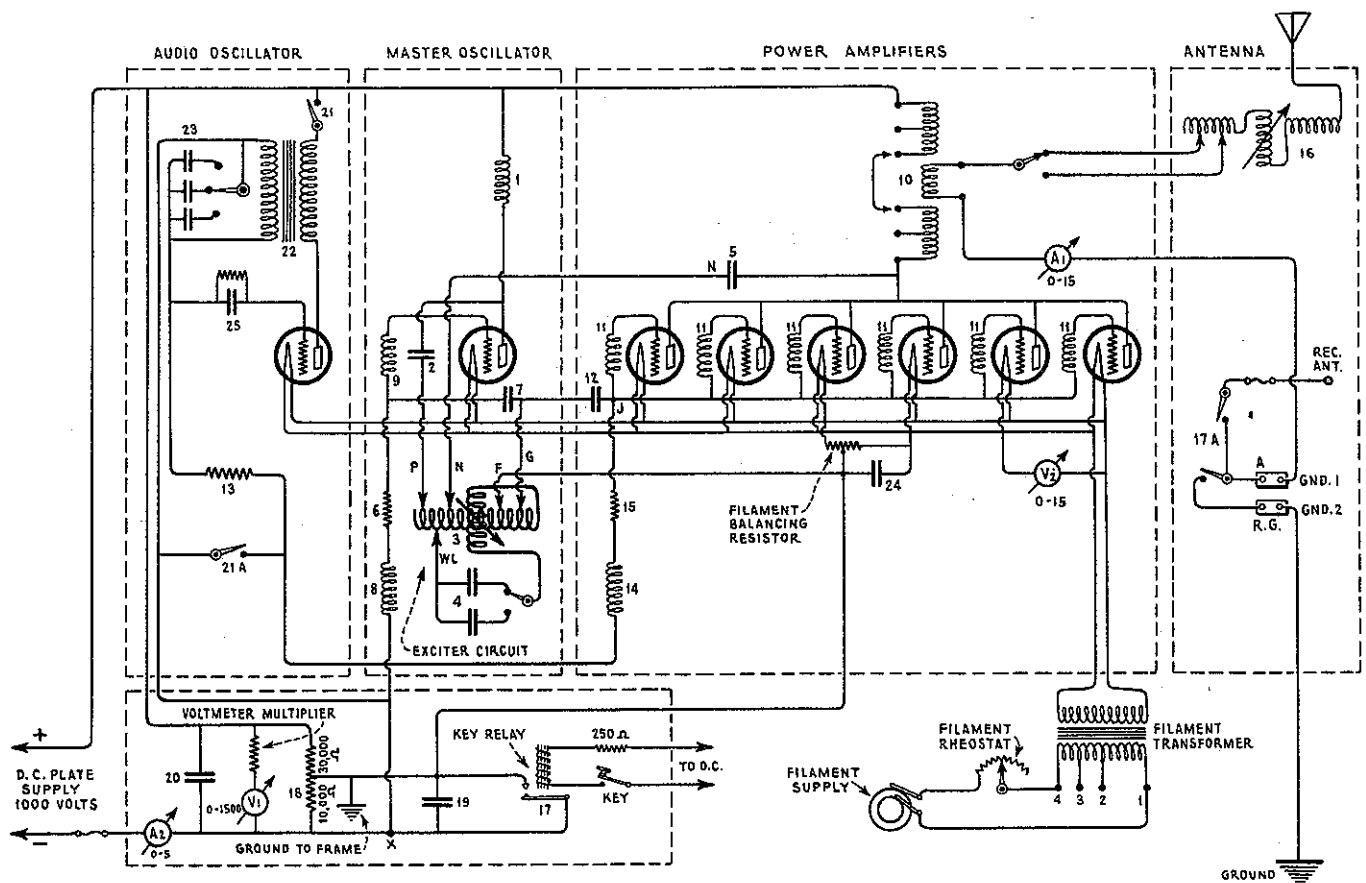


Figure 7

circuit elements and antenna tuning elements, whereas two sets are actually provided, one for the 600 - 1250 meter range and the other for the 1250 - 2500 meter range. Either the long or short-wave range may be selected by the seven-pole double-throw switch marked "transfer switch" on the photographs. The tubes are connected to the long-wave circuits when this switch is thrown up, and to the short-wave circuits when it is thrown to the down position.

The two pointers with long handles, shown just below the hinged screen door about mid-way of the panel in Figure 5, control the master oscillator (exciter) circuits by means of which the desired transmitting frequency is obtained. Loading of the antenna circuit is accomplished with a tapped inductor equipped with a rotor coil to permit fine tuning adjustment by the variometer method. The knobs controlling the antenna tuning are located on the upper part of the front panel. The short-wave exciter circuit is placed on the left and the long-wave on the right. By again making reference to the schematic diagram it is seen that the exciter oscillatory circuit or frequency-determining circuit consists of the inductor labelled 3 and the condensers 4. The inductor is also provided with a rotor coil which permits the variometer principle to be employed for changing the frequency. The plate and grid of the oscillator tube are connected to the tuned circuit by leads P and G through by-pass condensers 2 and 7 respectively. The filament is attached to the oscillator circuit through lead F. As previously stated, in the actual transmitter two of these inductors are supplied with the transfer switch to place either in the circuit, depending on the frequency desired.

Two control knobs on the panel, each marked "range switch", permit both the short-wave and long-wave ranges to be divided into two parts, namely: 600 to 900 meters and 900 to 1250 meters for the short-wave and 1250 to 1800 and 1800 to 2500 meters for the long-wave.

The following gives the approximate relation between antenna current and wavelength for the E.T. 3626-B when used with the average ship's antenna.

Wavelength	Antenna Current	Transfer Switch	Exciter Range	Antenna Inductance
600-900	10.1	Down	600-900 SW	600-900 SW
900-1250	10.0	Down	900-1250 SW	900-1250 SW
1250-1800	9.8	Up	1250-1800 LW	1250-1800 LW
1800-2500	9.4	Up	1800-2500 LW	1800-2500 LW

A key relay operated by power from a 110 V. d-c. supply, through a resistance and hand key, controls the grid circuits of both the master oscillator and amplifier tubes. While the key is up a negative bias of 250 volts is applied to all grids, thus stopping oscillation and insuring continued blocking of the plate current. The keying relay is also provided with additional contacts giving break-in operation. While the key is up the receiving set is connected to the antenna and the relay is adjusted to have the break-in contacts closed before the keying contacts close, and also to have the break-in contacts open after the keying contacts open.

The motor armature of the motor-generator set is provided with slip rings from which 77 volts, 60 cycle power is obtained for filament heating. A step-down

transformer gives the required filament input voltage with regulation through a rheostat. The d-c. generator for plate excitation is a two-pole shunt wound separately excited machine delivering a potential of 1000 to 1200 volts d-c.

Placing the E.T. 3626-B into Operation: 1. Before starting the motor-generator set turn the filament and generator field rheostats to minimum voltage positions and close the main line switch if it has been opened.

2. To start the motor generator set press the "start" button located on the the operator's control unit and adjust the filament voltage to 10 volts by means of the rheostat which is also mounted in this unit.

3. The plate voltmeter should be observed while making adjustment of the generator field rheostat until a reading of 1000 volts is obtained. The plate current ammeter should read about 1.2 to 1.4 amperes.

4. The transfer switch should be thrown up if transmission is desired on the long-wave range between 1250 and 2500 meters, or down for the short-wave range between 600 to 1250 meters.

5. The exciter tuning and range switch on the lower part of the panel is next placed in the wavelength position desired, the short-wave range being on the left and the long-wave range on the right.

6. The above wavelength adjustments are followed by placing either one of the antenna tuning switches in their proper position according to the range desired, the short-wave range switch is on the left and the long-wave switch on the right. The operator must be careful to place the exciter range switch in correct position corresponding to the exciter range switch for a given wavelength.

7. The "test" button on the panel may be depressed in order to ascertain if maximum antenna current will be obtained for a certain wavelength which will be indicated by the antenna ammeter deflection. To obtain the best adjustment, turn the antenna tuning control until the antenna ammeter indicates a maximum current. This tuning adjustment is attached to the variometer rotor coil and consequently it may be manipulated for any particular wavelength; it resonates the radiating circuit with the closed circuit.

8. When satisfactory radiation indication is secured after tuning the set as outlined above, the sending key may be operated for the transmission of messages.

9. Before sending a message be sure the "CW - ICW" switch is in proper position which, of course, is governed by the type of receiver employed at the station with which communication is to be established. When the sending key is closed, and the "CW - ICW" switch is thrown to the ICW position, the audio oscillator will generate one of three tone frequencies operating in conjunction with the master oscillator and radio amplifiers. The "tone frequency switch" located in the right hand side of the transmitter frame should not be touched while the motor-generator set is running as the d-c. voltage is on the circuits.

10. When communication is completed the set is shut down by pressing the "stop" button on the operator's control panel.

Theory of Operation. Referring to the schematic diagram in Figure 7, only one coil system called the "exciter" circuit, involving the generation of oscillations, is shown since the circuit is fundamentally alike for the two wavelength bands. Only one antenna variometer (16) is shown for the same reason although two such coils are in the actual set.

Looking at the set from the front, the left hand tube is used as the master oscillator, coupled to a split inductance or "Hartley" type circuit to produce oscillations. In the diagram this tube is the second one from the right with its oscillating circuit (exciter circuit) consisting of variable inductance (3) and two fixed condensers (4). The capacitance of these condensers is .004 mfd. and .002 mfd. respectively and function in conjunction with the long and short-wave exciter. The feed-back voltage built up across inductance (3) between the taps marked G and F is used to excite the oscillator grid through the coupling condenser (7). This condenser blocks the d-c. grid current from the oscillating circuit. The loss of high-frequency energy in the grid leak and keying circuit is prevented by the choke (8). The correct negative grid bias for the oscillator is obtained by the use of the 5000 ohm grid leak resistor (6) which acts to hold back a certain quantity of electrons on the grid when oscillating. The positive d-c. voltage is fed to the oscillator plate through a choke (1) which prevents the radio-frequency from backing up in the power supply circuit. The plate blocking condenser (2) has a capacitance of .004 mfd. it being inserted in the plate lead P connecting to the oscillatory circuit to furnish a low reactance path for the high-frequency a-c. component of the fluctuating plate current. The d-c. component is blocked by this condenser and flows through choke (1) and to the generator. The inductance (3) is varied by means of the rotating coil marked on the diagram with a long arrow, while the actual control knob on the transmitter panel is labelled either "short-wave" or "long-wave exciter tuning". The neutralizing condenser (5) has a capacitance of .00014 mfd., it being designed to prevent any reaction effects due to coupling between the amplifier circuit and the master oscillator - a condition always present because of the self-capacity (grid to plate capacity) of the amplifiers. Choke (9) in the oscillator grid is used to prevent the production of ultra-high-frequencies generally known as "parasitic" oscillations.

The six amplifier grids are coupled to the master oscillator circuit through condenser (12) and receive their excitation from the adjustable lead G on the inductance (3). A .004 mfd. condenser (12) serves to by-pass the high-frequency oscillations while at the same time it blocks the d-c. bias voltage of the amplifiers obtained through the use of the grid leak resistor (15). This 100 ohm resistor operates to hold an adequate number of electrons on the amplifier grids thus furnishing the correct negative bias when the oscillations produced in the master oscillator circuit are being increased in power by the amplifiers. This condition obtains when the transmitting key is down.

The amplifier plates receive their excitation from the 1000 volt generator through the plate coil of the antenna coupling transformer (10). The choke (14) builds up a high reactance to radio-frequencies and blocks the flow of this energy through the grid leak and keying circuits thus preventing high-frequency losses.

Inductive coupling between the closed and open circuits is provided by antenna transformer (10). Two such transformers are included in the transmitter, the long-wave on the left side and the short-wave on the right side. The radio-frequency component of the plate current of the six amplifier tubes passes through the primary of (10) causing a rapid change in magnetism which acts on the secondary turns and, as a consequence, an alternating e.m.f. is induced in the latter coil which sets the antenna system into excitation. The large output power of the amplifier tubes is delivered to the antenna in this manner. The 6.0 mfd. condenser (20) furnishes a low reactance path around the generator for the radio-frequency component. For a given plate voltage the amount of power transferred to the antenna is controlled by the ratio of turns in transformer (10). For example, a larger number of turns used in the secondary, or antenna coil, than in the primary will increase power. The proper relation of turns is made at the time the set is calibrated and does not require adjustments by the operator. Loading the antenna is accomplished with a tapped inductance (16) provided with a rotor coil for fine tuning the antenna by the variometer method. It has been previously stated that two such devices are included in the transmitter and controlled by knobs on the front of the panel.

Small choke coils (11) are connected in the grids of the power amplifier tubes and are placed as close to the tube sockets as practicable. The function of these chokes is similar to choke (9) in the master oscillator grid circuit.

The transmission of telegraph signals is by the keying relay (17) controlled by the hand key, the latter being energized from the 110 volt d-c. supply. The auxiliary contacts on relay (17) are shown in the antenna circuit at (17A). Break-in operation is provided by the closing of the auxiliary contacts preceding the closing of the grid circuit contacts. The diagram shows the connection of the grid return from all tubes to the negative 1000 volts at point marked "X" and the filament circuit to the tapped point on resistor (18). This resistor is attached to positive and negative of the d-c. generator and serves as a potentiometer. The amplifier grid return is through switch contact (21A) when CW transmission is employed. It should be particularly observed that the negative 1000 volts is not grounded, but as previously mentioned the ground is formed at the tapped point on potentiometer (18). According to the principles explained by Ohm's Law we know that a drop in voltage of a definite amount will result in the windings of this resistance when current flows through. The amount of the voltage, in this instance called "bias voltage", depends upon the strength of the current and the resistance of the unit (18) measured in ohms. Hence, when the sending key is up radio energy cannot be radiated because the large negative bias obtained from (18) is applied to the grids and oscillation stops. Subsequently a current of low value passing through potentiometer (18) from the d-c. generator places a holding bias on the grids. The total resistance of the potentiometer is 20,000 ohms. It consists, however, of two separate resistors joined in series. When the key is depressed, as for sending, a short circuit is placed across part of the potentiometer resistance from which the bias is obtained. This short, of course, removes the bias, since no voltage drop can then be obtained. The 1.0 mfd. condenser is an arc absorption unit connected in shunt with the contact points of key relay (17). Large potential surges, due to keying the circuit, are absorbed and dissipated by the 6.0 mfd. condenser (20).

ICW telegraphy is accomplished by modulating the output of the power amplifiers with an audio-frequency current obtained from the audio oscillator circuit consisting of three capacitors labelled (23) and the secondary winding of the iron core transformer (22). The tube functioning in conjunction with this circuit is known as the audio oscillator tube, the first tube on the left in the schematic diagram. The production of an oscillating current in the audio-frequency range is possible through the feed-back of power from the plate or primary winding of (22) to the grid or secondary which action takes place due the changing magnetic flux permeating the iron core which always accompanies any variation in the strength of the plate current. The plate and grid circuits are made resonant to a low frequency current by employing large condensers of high capacitance and building up the inductive reactance of the circuit through the use of windings composed of a large number of turns together with an iron magnetic circuit. The grid of the audio oscillator connects to one side of the secondary winding of (22) and receives its excitation from the alternating voltage of low frequency induced in this winding from the fluctuating plate current in the primary. The opposite end of the secondary is joined to the negative 1000 end of the potentiometer (18) at point "X".

In order to carry on ICW telegraphy with this transmitter the "CW - ICW" switch on the panel is thrown to position marked "ICW", thus closing switch (21) in the schematic diagram. The closing of this switch supplies power to the audio oscillator tube plate from the d-c. generator, while at the same time switch (21A) opens and removes the short circuit around resistor (13) and the secondary winding of transformer (22). The audio oscillator grid return is completed at point "X" which provides this tube with a blocking bias for keying similar to the conditions existing in the grids of the other tubes in the transmitter when the sending key is up. An inspection of the diagram shows that when switch (21A) is open the grid leak current of the six power-amplifier tubes must flow through resistor (13) and the secondary of transformer (22). Because of this interrelation between the radio and audio circuits the low frequency a-c. voltage induced across the secondary by the fluctuating plate current in the primary is effectively applied on the grids of all the radio power-amplifiers because these tubes are arranged in parallel, i.e., all of the grids are connected to one common junction which leads to condenser 12, and also to grid leak circuit consisting of choke (14) and leak resistor (15).

When the sending key is depressed the output of the audio oscillator is impressed upon the grids of the amplifiers, while these tubes are at the same time continuing to step-up the strength of the continuous oscillations received from the master oscillator. It follows that for any change in grid potential at an audio rate the amplitude heights of the continuous oscillations will be forced to vary in exact accordance with the wave form of the audio energy. It is then said that the CW energy is modulated with the frequency of the audio oscillating circuit. The CW energy is known as the "carrier" frequency and it will be recalled that this frequency was generated in the circuits of the master oscillator and amplified through the power tubes. Hence, an ICW signal or better, a modulated wave signal, is transmitted which produces a signal in the distant receiving set having a characteristic spark tone. The term "tone modulation" may also be applied to this variety of telegraphic transmission.

The audio oscillator circuit can be adjusted to three different tone fre-

quencies by varying its capacitance. Three condensers marked (23) and a switch making suitable connections is provided for this purpose. By proper selection of condensers, two of which are rated at .5 mfd. each, the third at 1.0 mfd., the tube grid bias can be made to vary at a 500, 700, or 1000 cycle rate, approximately.

When operating ICW, overloading of the audio oscillator with d-c. current from the power-amplifier grids is prevented by resistor (13) which also acts as a grid leak resistance for the amplifiers in addition to resistor (15).

The grid return of all tubes terminates at a tapped point on the filament balancing resistor shown in the diagram. The insertion of this small amount of resistance in the grid circuit requires the use of the .5 mfd. by-pass condenser (24) in order to provide a path of low reactance to the radio-frequency energy. While the audio oscillator functions normally during ICW transmission, a negative bias of correct value is maintained upon its grid by the 5.0 mfd. grid condenser and 3000 ohm leak resistor marked (25) on the diagram. During CW operation the audio oscillator ceases to function because switches (21) and (21A) are open, and at this time the grid leak circuit for the power amplifier tubes is through grid leak resistor (15), r.f. choke (14) and switch (21A) which is then closed and thence to the negative 1000 volt side of potentiometer resistor (18) indicated on the diagram at point "X".

The instruments on the transmitter panel are labelled on the schematic diagram as follows: A1 is the antenna current ammeter (0-15 amps.) which is necessary to ascertain when resonance is established between the closed and open circuits on any of the transmitting waves while adjusting the antenna variometer controls; A2 is the plate current ammeter (0-5 amps.) which records the amount of direct current flowing from the d-c. generator to the plates of all eight tubes; V1 is the plate voltmeter equipped with a 0-1500 volt scale and used in conjunction with the multiplier resistance to indicate the positive plate potential applied to the plates, and V2 is the filament voltmeter with a range of 0-15 volts used to indicate the input e.m.f. applied to the filament terminals which provides the correct filament temperature. The radio-frequency chokes 1, 8 and 14 are 400 turn duolateral wound coils.

Troubles and Emergency Measures. It will be found that a majority of the suggestions contained in the following paragraphs are applicable to various types of vacuum tube transmitters.

Defective Tubes. Should any of the tubes become inoperative and no spares are available, the transmitter may still be operated with three or four amplifier tubes in place of the usual six. The plate voltage should be reduced to prevent overheating of the plates of the tubes. Care must be taken that the tube plates do not exceed a dull red. The master oscillator tube, (the front left hand tube), must always be used. ICW transmission cannot be accomplished without the left hand rear tube which is the audio oscillator, because this transmitter is not equipped with a chopper.

Plate Radio Frequency Choke Coil Burned Out. Should the master oscillator plate choke, marked (1) in Figure 7, burn out remove the defective plate choke and replace it with grid choke (8) being careful to put in a temporary wire

jumper to close the grid circuit. This provides an immediate remedy but it will be observed that the efficiency of the master oscillator will be impaired. A 400 turn honeycomb or duolateral coil may be used for the plate choke if one is available.

Shorted Plate or Grid Blocking Condenser. This difficulty may be remedied by removing the defective condenser and substituting one of the large condensers in the other wavelength band. The substitute condenser can be easily mounted in a temporary position by lengthening the connecting leads.

Filament Voltmeter Inoperative. The filament rheostat should be adjusted until the tubes begin to heat or the antenna current drops quickly. When this effect is observed the rheostat should be adjusted slowly in the opposite direction until the temperature of the tubes becomes normal and the antenna is not rising rapidly.

No Indication on the Antenna Ammeter. The antenna circuit may not be in resonance or the trouble may be due to loose connections. Examine the antenna variometer and coupling transformer in the wavelength range that is inoperative. Also, look for open switch blades in the transfer switch. If this trouble is thought to be due to a burned out ammeter place a wire jumper between the meter terminals and note the results. If this is found to be the seat of the trouble without an ammeter reading the only alternative is to adjust the circuits in accordance with the tuning record and observe the plate current ammeter for final resonance.

Burned Out Plate Ammeter or Voltmeter. If the voltmeter is burned out no temporary repair is possible, therefore it is suggested that the generator field rheostat be adjusted to its usual position and the tubes watched closely to prevent overheating of the plates. In the case of a burned out plate ammeter a 150 watt lamp can be connected to the meter terminals, and for normal operation the lamp should not exceed full brilliancy.

Burned Out Filament Transformer: Filament Rheostat in the a-c. Supply Discontinued From the Two Slip Rings on the Motor Armature. The filament circuit should be disconnected from the filament transformer secondary and then connected to the terminals of a storage battery as follows: Connect five cells in series and then attach the filament terminals across the five cells. The connecting leads should be capable of carrying 30 amperes. The cells should be of the lead-acid type. A rheostat control will not be required because the voltage of the five cells is practically correct, i.e., 10 volts.

Burned Out Grid Leak. Should the grid leak of the power amplifier burn out it may be replaced by an equal value of resistance approximately 4000 to 10,000 ohms. A satisfactory substitute may be made up with a rubber hose about 10 inches long, filled with water and plugged at each end with a connecting wire passing through each plug and protruding a short distance in the water to form suitable electrodes.

Motor Generator. If the machine fails to start when the "start" button is pressed, look for an open main switch on the starter panel or a defective

main fuse. The operator should ascertain if there is line voltage at the main switch and if it is of the correct value. A test for line voltage may be easily made by depressing the telegraph key which should cause the relay key to work, providing the ship's power is on.

If the contactor in the automatic starter closes when the "start" button is pressed but the motor generator armature fails to rotate the trouble might be due to a burned out starting resistance on the back of the starting panel, or look for loose connections.

A frozen bearing will prevent any movement of the armature. To ascertain this condition first open the main switch and, with the power off, turn the armature over by hand and at the same time inspect the oil wells and rings to see that they have plenty of oil.

Tube Filaments do not Light. If the motor generator starts up satisfactorily but the filaments fail to light look for blown fuses on the terminal board which might happen provided a tube filament has been previously short circuited. Also look for defective brush or insufficient brush tension on the motor slip rings, or loose connections.

Tubes Overheating. It is possible that a low voltage bias caused by a defective potentiometer resistance will not block the tubes sufficiently. Or, the bias voltage may be partially short-circuited by an amplifier tube which has become soft, this condition being generally evidenced by the troublesome tube showing a blue haze and heating more than the other tubes.

If, on the other hand, the tubes only overload while the key is down the master oscillator tube may be defective, that is, oscillations are not being generated in the oscillator's tuned circuit. In order to localize the possible reason for this trouble remove the six amplifier tubes from their sockets but keep the master oscillator and audio oscillator tubes in place. When the key is now depressed the oscillator tube will heat excessively if the tube or circuit is defective. However, if the amplifier plates exceed a dull red glow with the key down and the antenna in resonance it may be assumed that an incorrect number of plate turns is used or the antenna coupling transformer is defective.

Audio Oscillator Circuit Fails to Operate. For the location of this trouble look at all connections on the "CW - ICW" switch, audio transformer (22) and condensers and switch (23) indicated on the diagram in Figure 7. The audio oscillator tube may be defective and the remedy in this event is obvious. One of the three condensers (23) may have broken down. Should the plate current rise excessively when the key is pressed while the audio oscillator seems to function properly the trouble may be due to either a shorted amplifier grid leak or audio oscillator grid leak, both of which have a rating of 3000 ohms.

Observe the Following Precautions. Never clean commutators with the motor generator set running as the high voltage is dangerous. Do not change tubes, make adjustments, or come into contact with the wiring while the set is in operation.

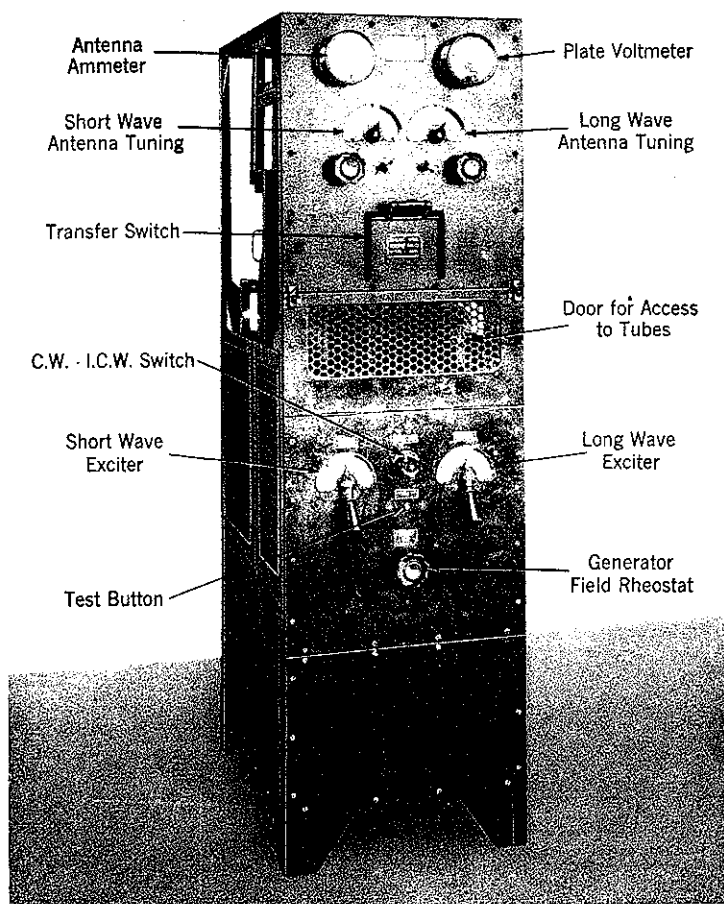


Figure 8

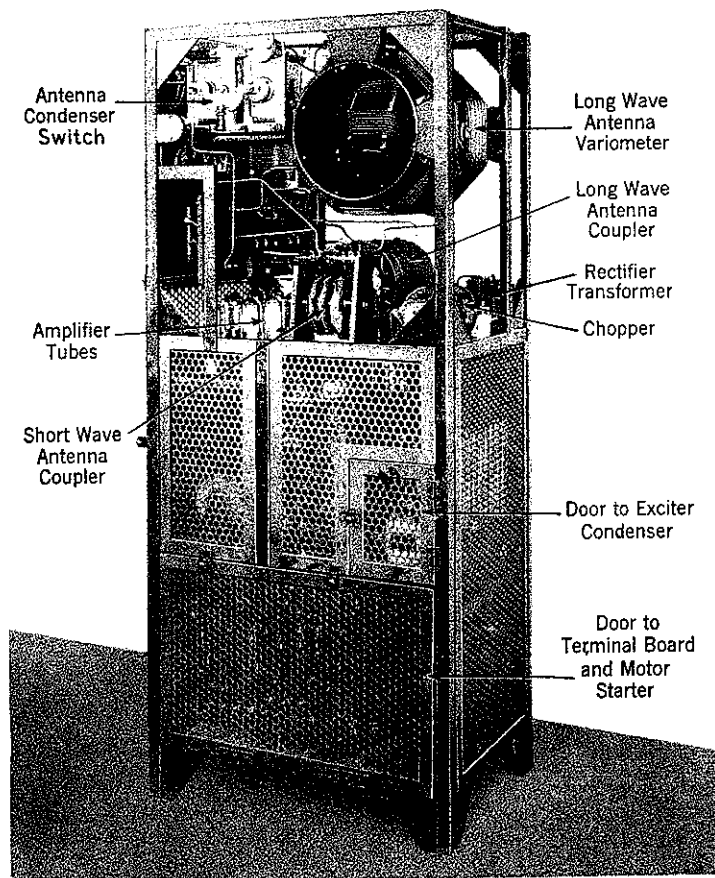


Figure 9

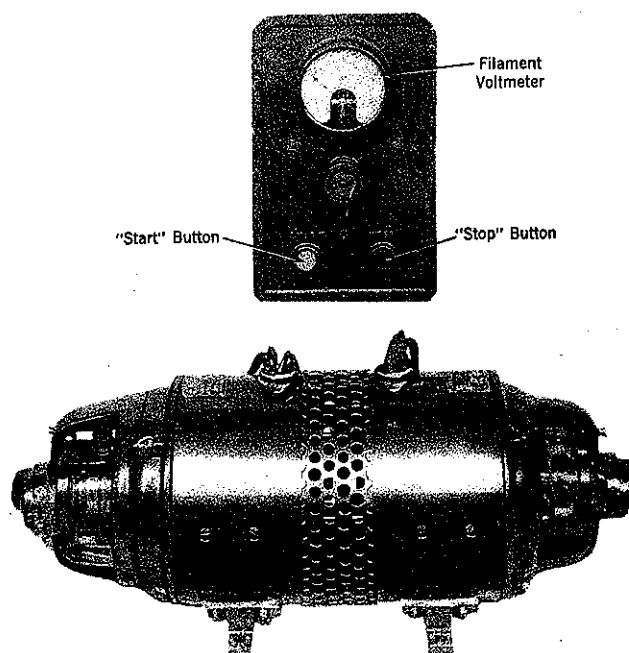


Figure 10

E.T. 3626 Telegraph Transmitter 750 Watts. The front view of this transmitter is shown in Figure 8 and a side view in Figure 9. The motor generator and operator's control panel are illustrated in Figure 10. Transmission on two wavelength bands are provided through the use of a transfer switch and two independent sets of tuning elements. These bands are 600 to 1250 meters and 1250 to 2500 meters. Interrupted continuous wave transmission is obtained by a chopper system which causes the radiated signal to have the characteristic tone of a 500 cycle spark transmitter.

A total of eight UV-211 fifty watt tubes are utilized in this equipment. Six tubes connected in parallel are used as power-amplifiers which feed their output into the antenna system through a coupling transformer. One tube is employed as the master oscillator or exciter. Facing the panel the master oscillator is the left hand front tube; it utilizes the split inductance or "Hartley" method of feed-back to produce oscillations. Another tube located directly in back of the master oscillator, i.e., in the left hand rear corner of the tube rack, is used as a rectifier. This tube charges a 1.0 mfd. condenser to a potential of approximately 250 volts. Power for this circuit is obtained from the 77 volt, 30-cycle filament supply and passes through a small transformer which steps up the voltage to 250 volts and the tube rectifies this voltage for introduction to the keying circuit. While the sending key is up a negative potential of 250 volts is applied to the grid circuits of the master oscillator and the power amplifiers to stop oscillation and insure continued blocking of the plate current. The grid bias voltage is automatically controlled by the manipulation of the hand key which in turn actuates a relay with two pairs of contacts. The relay contacts are arranged in such a manner to first open the grid circuit, stopping oscillation, and immediately after permitting the negative 250 volt bias to be applied while the key is up as previously mentioned. A second relay device provides break-in operation by connecting the receiving set to the antenna when the key is up.

The motor armature of the motor-generator is provided with two slip rings from which the a-c. power is obtained for filament heating. The filament transformer receives the 77 volts, 30 cycles, single phase power through a rheostat and steps down this voltage to the value required by the filaments, i.e., 10 volts. The power for plate excitation is delivered by a two-pole compound wound generator giving a d-c. potential of 1000 to 1200 volts.

The fundamental oscillator, power amplifier, and tuning circuits in this transmitter are quite similar to those in the E.T. 3626-B equipment. The theory of operation and other information relating to the main circuits may be fully understood by making reference to the discussions on transmitter E.T. 3626-B given in previous paragraphs. The principal change that has been made is in the method employed for obtaining the 250 volt grid negative bias. In the E.T. 3626-B it is obtained from the voltage divider or potentiometer connected across the positive and negative 1000 volts of the generator, whereas in the E.T. 3626 this potential bias is furnished by one tube which functions as a rectifier as explained in the foregoing paragraph.

Since this transmitter does not contain an audio oscillator circuit it requires the use of a chopper system in order to provide ICW transmission. The motor driven chopper commutator interrupts the tube grid circuits at a 500

cycle rate, approximately, to give tone modulation or modulated CW signals. However, in commercial service signals of this type are called ICW. The chopper is placed in operation by the "CW - ICW" switch on the front of the panel. It should be noted that the antenna current will be somewhat less than when straight CW is used.

E.T. 3626-A 750 Watt Transmitter. This transmitter uses a total of eight tubes of the UV-211 type. Six of these tubes are connected in parallel and operate as power amplifiers while the remaining two, also connected in parallel, are the master oscillators. The front and rear tubes at the extreme left of the tube rack are the oscillators. An audio oscillator circuit is not included hence a motor driven chopper is used to give ICW transmission. Keying is uni-wave and the negative 250 volt keying bias is supplied from a potentiometer. The circuit arrangement of the oscillator, power-amplifier and antenna circuits are similar to those in models E.T. 3626 and E.T. 3626-B.

200 Watt Model E.T. 3627-A Transmitter. Figure 11 shows a front view of this continuous wave and interrupted continuous wave vacuum tube transmitter. A rear view is shown in Figure 12. The fundamental circuit of this transmitter is shown in Figure 13. An adjustable positioning device for the master-oscillator variometer permits any five frequencies within the 300 to 312 kilocycle band to be selected and kept in a permanent adjustment. This provides a convenient arrangement, for in changing from a calling to a working frequency the operator is not required to make careful adjustments to locate an exact position on the scale with the master-oscillator pointer.

Theory of Operation. The theory of operation of the 200 watt E.T. 3627-A transmitter may be understood by referring to the schematic diagram in Figure 13. The frequency of the UV-211 master-oscillator tube is controlled by the variometer L4 which operates in a capacity-coupled (Colpitt's oscillator) circuit. The grid alternating e.m.f. necessary for the production of continuous oscillations is obtained from the voltage drop across condenser C7. The values of capacitance of the three condensers C1, C6 and C7, and the inductance of variometer L4, are carefully selected because they represent the circuit constants and therefore determine the frequency range of the transmitter. Condenser C5 is the usual plate-blocking condenser and serves to keep the d-c. plate voltage off the grid and oscillatory circuit of the master-oscillator tube. This condenser of .003 mfd. capacitance provides a low reactance path for the radio-frequency component of the total plate current allowing it to flow into the oscillatory circuit for the requisite feedback of plate energy into the grid. Radio-frequency choke L3 keeps the plate high-frequency component from backing into the 1000 volt generator circuit. The grids of the two UV-211 power-amplifier tubes are directly connected and these grids are excited by radio energy through condenser C9 and resistance R4, at the frequency of the oscillatory circuit. Grid leak resistor R1 maintains the correct negative bias on the amplifiers, and radio-frequency choke L2 prevents losses of the high-frequencies through the grid leak circuit. The grid leak on the master oscillator tube is resistor R3. The high-frequency energy in the power amplifier plate circuit feeds into the primary (pri.) or plate coil of the antenna transformer. This coil is also called the "tank inductance". The antenna is set into excitation through the transfer of this

high-frequency from the output of the radio amplifier tubes through the antenna transformer. The primary of this transformer carries the ICW and CW switch. It will be noticed that in the case of interrupted continuous waves the amount of inductance used will never be as great as for straight CW. This feature allows the radiated wave of the ICW variety to possess sharp characteristics. The frequency of the master-oscillator is repeated in the output of the power-amplifiers, and the antenna circuit is adjusted for resonance to this frequency by the four taps and variometer on the antenna loading inductor L1.

Key Relay. A rapid change-over from send to receive is provided by the magnetically operated break-in relay which is shown mounted on the front of the panel in Figure 11. This relay is designated as K2 in the schematic diagram. Modern radio traffic conditions require this feature to be provided in the transmitter. Keying speeds up to 40 words a minute are possible with the relay, it being equivalent to a double-pole, single-throw relay. The low side of the antenna contains one pair of contacts connected in series and during the transmitting periods they serve to short circuit the input to the radio receiver. In order to prevent sparking at the antenna contact and also to reduce the disturbance from clicks in the radio receiver, the second pair of contacts key the transmitter proper and are adjusted to close slightly after and open slightly before the antenna circuit contacts.

Keying Circuit. The explanation of the fundamental keying circuit will be understood by reference to the schematic diagram where it is seen that the negative lead from the 1000 volt generator connects to one of the key contacts on the break-in relay. The negative plate circuit is completed through the upper right contact to the mid-tap on the filament heating transformer T2. The grid return leads of both the power amplifiers and master oscillator are returned to this negative side of the plate circuit through grid leak resistors R1 and R3, respectively. Both the negative plate circuit and the grid circuit are broken by the keying action with the result that a high negative potential is impressed upon the grids of the tubes whenever the contacts open. The relay contacts will interrupt a large current with minimum sparking.

Legend and Function of Component Parts of E.T. 3627-A Transmitter, Figure 13.

A-1 Antenna ammeter (0-10 amperes) is used to indicate resonance between the tank inductance, or plate coil Pri and antenna system.

A-2 Plate ammeter (0-2 amperes) indicates direct current drawn from the plate generator by the three tubes.

C-1 Master oscillator plate condenser, .003 mfd. is used for plate excitation of this tube.

C-2 Filter condenser, 1 mfd, acts to smooth out any ripples in the d-c. from the 1000-volt generator due to commutation.

C-3 Filament by-pass condensers, .5 mfd. each, furnish a low reactance path for the radio-frequency oscillations from grid to filament. Without these condensers the filament heating coils on the iron core transformer T2 would form the only path which would obviously impede the flow.

- C-4 Key condenser, .015 mfd. functions to absorb and dissipate transients of potential surges set up while keying. This condition is manifested by arcing.
- C-5 Master oscillator plate blocking condenser, .003 mfd., permits the high-frequency oscillating component of the plate current to flow through readily, but prevents the d-c. component of the plate supply from being impressed on the oscillator grid or passing to the a-c. tuned circuit.
- C-6 Master oscillator plate condenser, .002 mfd., functions similarly to C1 and forms a part of the oscillatory circuit.
- C-7 Master oscillator grid condenser, .002 mfd., is the grid input or excitation condenser and from across its plates is obtained the requisite voltage drop to be applied between grid and filament for maintaining the master oscillator and associated circuits in a state of generating continuous oscillations.
- C-8 Chopper condenser, .003 mfd., used in conjunction with resistor R9 helps to smooth out any unevenness in the chopper note in order to produce a clear and distinct tone in the telephone receivers.
- C-9 Power amplifier grid condenser, .003 mfd., permits the high-frequencies generated in the master oscillator circuit to pass through and excite the grids of the two radio-frequency power tubes.
- F-1 Plate fuse rated at 2 amperes (not shown)
- F-2 Receiver antenna fuse, .5 ampere (not shown).
- K-1 Hand key used for interrupting the stream of radio oscillations generated in the transmitter into dots and dashes for the dispatch of radio telegraphic messages.
- K-2 Break-in relay (Key relay) permits a rapid changeover from send to receive, it being magnetically operated by the hand key.
- L-1 Antenna variometer and four tap inductance used for loading the antenna in order to establish resonance with the tank circuit.
- L-2 Power amplifier grid leak radio-frequency choke. To prevent losses in the grid leak circuit of the high frequencies flowing from the master oscillator through amplifier feed resistance R4 and condenser C9. These radio frequencies are intended to build up a high value of excitation voltage on the amplifier grids.
- L-3 Master oscillator plate choke is in series with the positive lead of the 1000 volt generator and functions to prevent losses by blocking out the radio oscillations from this circuit. These oscillations will flow readily through the low reactance path of C5.
- L-4 Master oscillator variometer permits any five frequencies within the 312 to 500 kilocycle range to be selected.

R-1 Power amplifier grid resistance, 500 ohms, furnishes correct grid bias for stable operation of the two UV-211 tubes.

R-3 Master oscillator grid resistance, 7500 ohms, maintains grid at correct bias or negative potential.

R-4 Power amplifier feed resistance, 150 ohms, used to maintain the radio-frequency voltage supplied to the power amplifier grids from the master oscillator at a normal value.

R-5 Filament rheostat, 20 ohms, permits a close control of filament terminal e.m.f. of all tubes for working the filaments at their rated temperature.

R-6 Master oscillator parasitic resistor, 15 ohms, (not shown) is used to suppress the generation of ultra high-frequencies caused by the plate to grid capacity of vacuum tubes and coupling leads which give such a circuit a definite oscillation period.

R-7 Plate field rheostat, 250 ohms, allows a fine control of the positive voltage applied to the plates of all tubes.

R-8 Power amplifier parasitic resistor, 15 ohms, (not shown) functions similarly to R6.

R-9 Chopper resistor, 50 ohms, works in conjunction with C8 to smooth out any unevenness in I.C.W. energy.

R-10 Key relay resistor, 400 ohms, (not shown).

S-1 Antenna inductance switch permits convenient change of wavelength from calling wave to communicating (working) wave.

T-1 Antenna transformer consists of tank inductance (plate coil) Pri and antenna coil S, and is used to provide magnetic coupling between the closed and open oscillatory circuits for the transfer of radio power. The tapped tank inductance connects to CW and ICW switch allowing the proper selection of inductance for either form of transmission.

T-2 Filament transformer, .125 K.V.A., is a mid-tapped step-down iron core transformer which receives power from a 40 cycle supply from collector rings attached to the windings of the motor, and delivers an alternating current of 10 volts, when regulated, for heating the filaments resulting in an adequate electron emission.

V-1 Filament voltmeter, 0-15 volts a-c. should read 10 volts after completing the voltage adjustment by means of the filament rheostat R5.

V-2 Plate voltmeter, 0-1500 volts d-c. indicates the positive plate potential applied to each of the three plates.

Y-1 Chopper motor is rated at 1/50th horse power and is driven from 110 V. d-c. supply. When ICW transmission is desired the signal switch should be placed in ICW position closing one pair of contacts which starts the chopper motor and

opening a second pair which removes the short circuit maintained around the chopper during CW transmission. A brush resting on the chopper wheel alternately makes contact with a copper and fibre segments thus causing the grid circuits of the master oscillator and power amplifiers to be broken at the rate of approximately 1000 times a second to radiate a wave having the general characteristics of the note produced by a 500-cycle spark transmitter.

Vacuum Tubes. Facing the transmitter panel, the tube at the left is the master oscillator and the remaining two tubes to the right are the power amplifiers, both being connected in parallel. In the schematic diagram, Figure 13, this order is reversed, where it may be seen that the master oscillator is drawn at the right and the two power amplifier toward the left.

The evaluations given in the following table will enable the operator to ascertain the practical relation between the operating wavelengths and the currents in the various circuits. The positions of the antenna variometer pointer on the scale, indicated in degrees, and the antenna inductance switch, are also given.

When the E.T. 3627-A was used with an antenna having a capacitance of 0.0008 mfd. and resistance of four ohms the following results were observed, both for CW and ICW transmission.

Wavelength	Antenna current. Amperes	Plate current. in Amperes	Reading on Scales Position of Antenna Inductance Switch.	Position of Antenna Variometer Switch.
CW 600	7.1	0.59	55 degrees	1
ICW 600	4.75	0.39	55 degrees	1
CW 800	7.1	0.6	41 degrees	2
ICW 800	4.6	0.39	41 degrees	2
CW 960	7.25	0.61	102 degrees	2
ICW 960	4.6	0.41	102 degrees	2

A different set of results was obtained with the transmitter working into an antenna possessing the following characteristics, namely, a capacitance of 0.0004 mfd. and resistance of four ohms.

CW 600	6.1	0.5	45 degrees	2
ICW 600	4.0	0.33	45 degrees	2
CW 800	6.4	0.5	70 degrees	3
ICW 800	4.0	0.32	70 degrees	3
CW 960	6.25	0.55	79 degrees	4
ICW 960	3.5	0.32	79 degrees	4

E.T. 3627 - 200 Watt Transmitter. This transmitter is of the master oscillator-power-amplifier type. There are three 50 watt type vacuum tubes used as follows: one UV-211 as the master oscillator and two UV-211 connected in parallel as power amplifiers. The photographs in Figures 14 and 15 show the location of the component parts. The power amplifiers step-up the voltage of the oscillations generated in the circuits of the master oscillator and feed

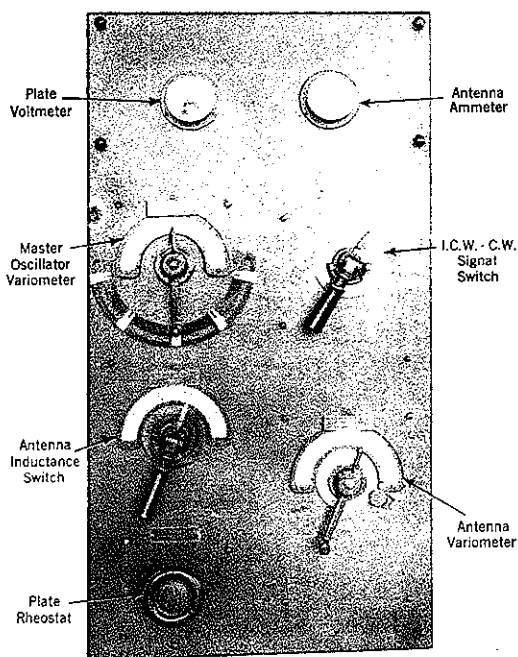


Figure 14

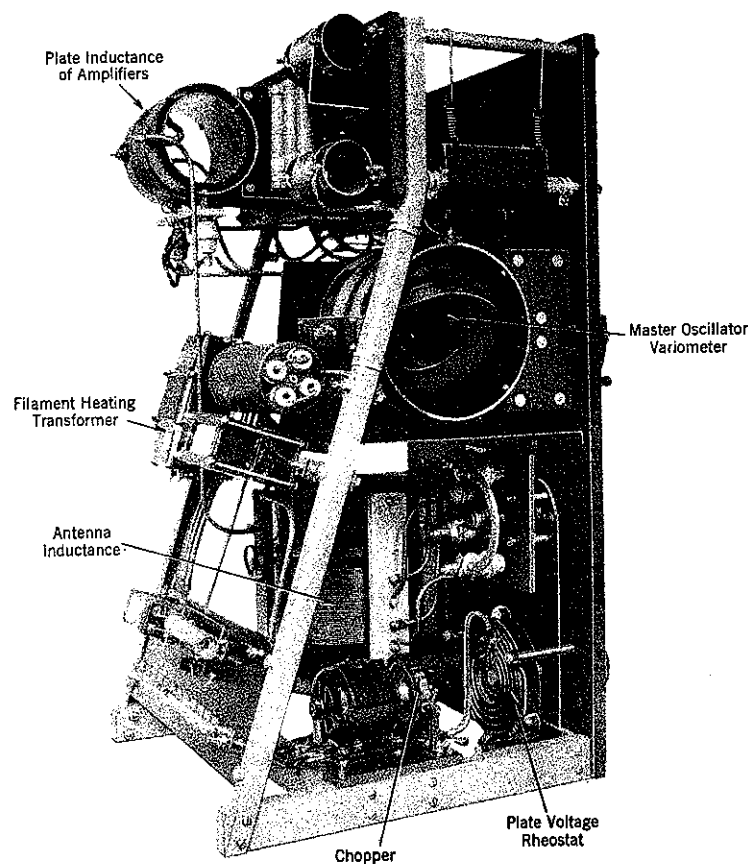


Figure 15

this increased power into the antenna system through the coupling transformer. The primary or plate coil of this transformer is called the "tank inductance". The grids of the power amplifiers receive their excitation from the master oscillator through the coupling or by-pass condenser. A resistor prevents overloading of the amplifier grids with radio frequency voltage. Continuous oscillations are produced by the "Colpitt's" method of feed-back which utilizes the voltage across the plates of the grid excitation condenser for grid excitation.

The principal circuits of the E.T. 3627 are substantially the same as those in the E.T. 3627-A transmitter just described. The E.T. 3627-A is different from the E.T. 3627 because of the slight modification made necessary to provide the E.T. 3627-A transmitter with break-in operation through a magnetically operated relay controlled by the operator's sending key.

Placing the E.T. 3627 in Operation. It is advisable before starting the motor generator set to turn all rheostat knobs to the extreme right. The "start" push button controls the automatic motor starter and when this button is pressed the motor-generator will come to speed in a few seconds. The filament rheostat should be adjusted until a filament voltage of 10 volts is obtained. The filaments are all connected in parallel and attached to a step-down transformer having an input frequency of 40 cycles supplied by two slip rings provided on the motor winding. The plate voltage is then adjusted by means of the plate rheostat until a normal working voltage of 1000 volts is observed on the indicating meter. The switch marked "CW - ICW" should be placed in the proper position.

determined by the type of transmission desired. If this switch is thrown to the ICW position the motor driven chopper will be set into rotation and the chopper commutator will function to interrupt the continuous oscillations. Communication with a distant station may now be carried on by closing the transmitting key. Before the key is operated the master oscillator variometer should be set at the desired wavelength by means of the handle provided for that purpose. While the key is pressed the antenna may be resonated by turning the handle marked "antenna variometer" which moves the rotor coil located within the loading inductor. The antenna wavelength is changed by means of the four-point switch which is operated by the long handle on the transmitter panel marked "antenna inductance switch". The inductance range of the transmitter is continuous because the range of the antenna variometer is sufficient to overlap the taps on the loading inductance. When the transaction of telegraphic business is completed the transmitter is placed out of operation by simply pressing the "stop" button.

In order to insure the radiation of a clear ICW note the chopper commutator should be smoothed off during periodic inspection of the transmitter units. A very fine grade of sandpaper should be used for this purpose, taking care to prevent unequal wear between the insulation and the copper segments. It is advisable at the same time to inspect the spring silver brushes for their proper tension against the periphery of the commutator wheel and make adjustment if necessary.

The current in the antenna system as read on the antenna ammeter and the plate current for various wavelengths from 570 to 1000 meters is given in the following tabulation in order to inform the operator regarding the average performance of the E.T. 3627. The values listed below were obtained with the transmitter used on an antenna having a natural period of 315 meters and when radiating a CW signal. The reading on the scales for each of the tuning control adjustments is also given. The tubes were supplied with normal working voltages of 1000 volts plate potential and 10 volts filament.

Wavelength	Antenna Current	Plate Current	Reading on Scales		Position of Antenna Inductance Switch
			Master Oscillator Variometer	Antenna Variometer	
			0	74	1
570	7.3	.6	20	107	1
625	7.3	.6	40	149	1
690	7.1	.58	60	41	2
750	6.9	.575	80	57	2
810	7.0	.58	100	72	2
858	7.0	.585	120	92	2
910	6.9	.585	140	114	2
945	6.9	.575	160	130	2
970	6.8	.565	180	137	2
1000	6.7	.56			

2-KW. Model E.T. 3638 Telegraph Transmitter. A front and rear view of this transmitter are shown in Figure 16 and 17, respectively, and the schematic diagram in Figure 18. An inspection of the diagram shows that the general arrangement of the master oscillator (M.O.) and power amplifier circuits are

somewhat similar to those employed in the E.T. 3627-A transmitter. The E.T. 3638 equipment, however, utilizes four vacuum tubes connected in parallel as intermediate power amplifiers (I.P.A.) and an "antenna loading inductance" in order to increase the frequency range of the transmitter. A ship's antenna with a low capacitance requires the use of an external loading inductance in order to permit transmission on the higher wavelengths. A photograph of the external loading inductance is illustrated in Figure 19. When this transmitter is used on an antenna with the proper characteristics it will cover a continuous wavelength band of 600 to 2400 meters, or a frequency range of 125 to 500 kilocycles.

The transmitter employs seven vacuum tubes, one 50-watt U V-211 as a master oscillator, four similar tubes arranged in parallel as intermediate amplifiers, and the remaining two tubes, type UV-851, as main power amplifiers. The two UV-851 tubes are shown in the front panel view protected by the screen door. These main amplifiers are rated at 1-kw., require a plate potential of 2000 volts d-c. obtained by adjusting the plate rheostat, and the filaments each draw 15.5 amperes a-c. when supplied with the specified terminal voltage of 11 volts. The five 50-watt tubes can be seen in the rear view of Figure 17. They require a normal working plate potential of 1000 volts d-c. and a filament input e.m.f. of 10 volts. The filaments are heated from 80 cycle power provided by slip rings on the motor winding through a step-down filament transformer. The filament voltage is regulated by rheostat R10. Since the 50-watt tubes require less filament voltage than the main power tubes the output of the filament transformer is connected to the lower power tubes through the resistor R7 which serves to drop the voltage on the latter tubes to the required value.

Theory of Operation. The E.T. 3638 is placed in operation on the desired wavelength by the selection of the proper positions for the master oscillator and the power amplifier band change switches. The master oscillator variometer marked L8 on the diagram is then placed at the desired wavelength as indicated on the scale provided for that purpose. In order to resonate the antenna with the closed oscillatory circuit for maximum current as read on the antenna ammeter the rotor coil of antenna variometer L2 is turned by manipulating the knob on the panel. After the most satisfactory adjustment has been found the position can then be indicated on the scale calibrated in degrees. It is necessary, of course, to supply power to the antenna system whenever the tuning adjustments suggested above are performed and this may be conveniently done by depressing the "test button". This button functions similarly to the operator's sending key and works the magnetic relay. The keying relay which provides break-in operation is shown in Figure 16. It permits the receiver to be connected to the antenna and the transmitter disconnected whenever the sending key is up. The motor-generator set is controlled in the usual manner by a "start-stop" push button located on the operator's table.

The circuit employed in the transmitter is of the "master oscillator, intermediate-power-amplifier, main-power-amplifier" type. The variometer L8 and condensers C8, C9 constitute the frequency-determining circuit. The requisite voltage for grid excitation of the oscillator is obtained from the voltage across the plate of condenser C9. Condenser C6 is the plate by-pass condenser and serves as a low reactance circuit for the flow of the high frequency component of the plate current.

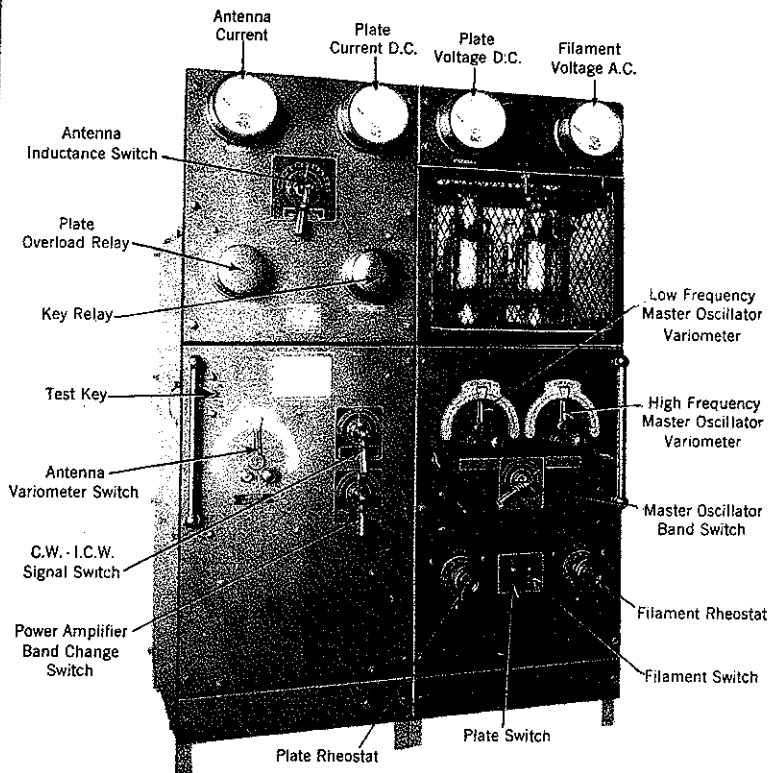


Figure 16

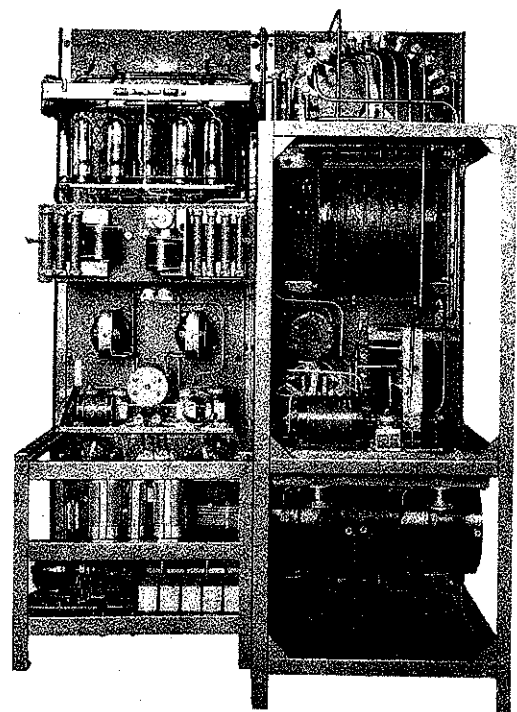


Figure 17

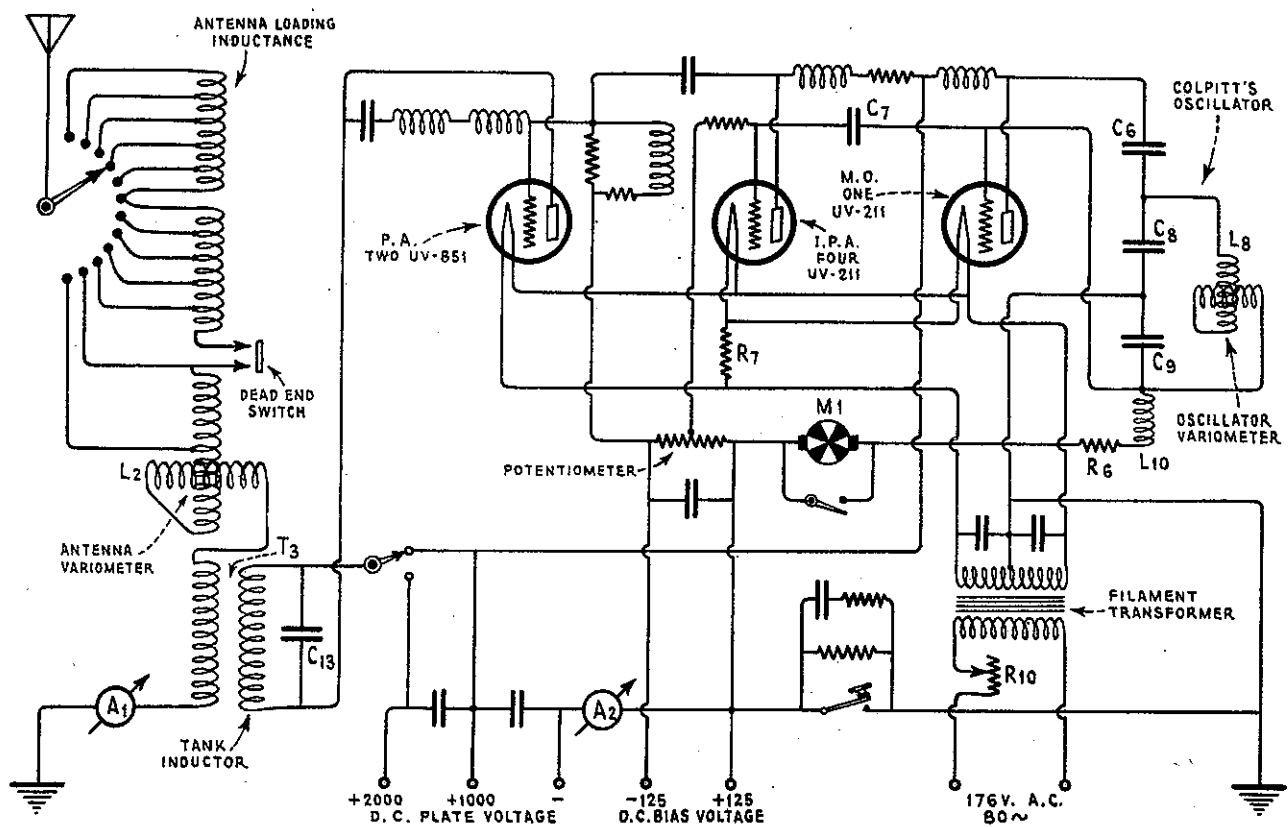


Figure 18

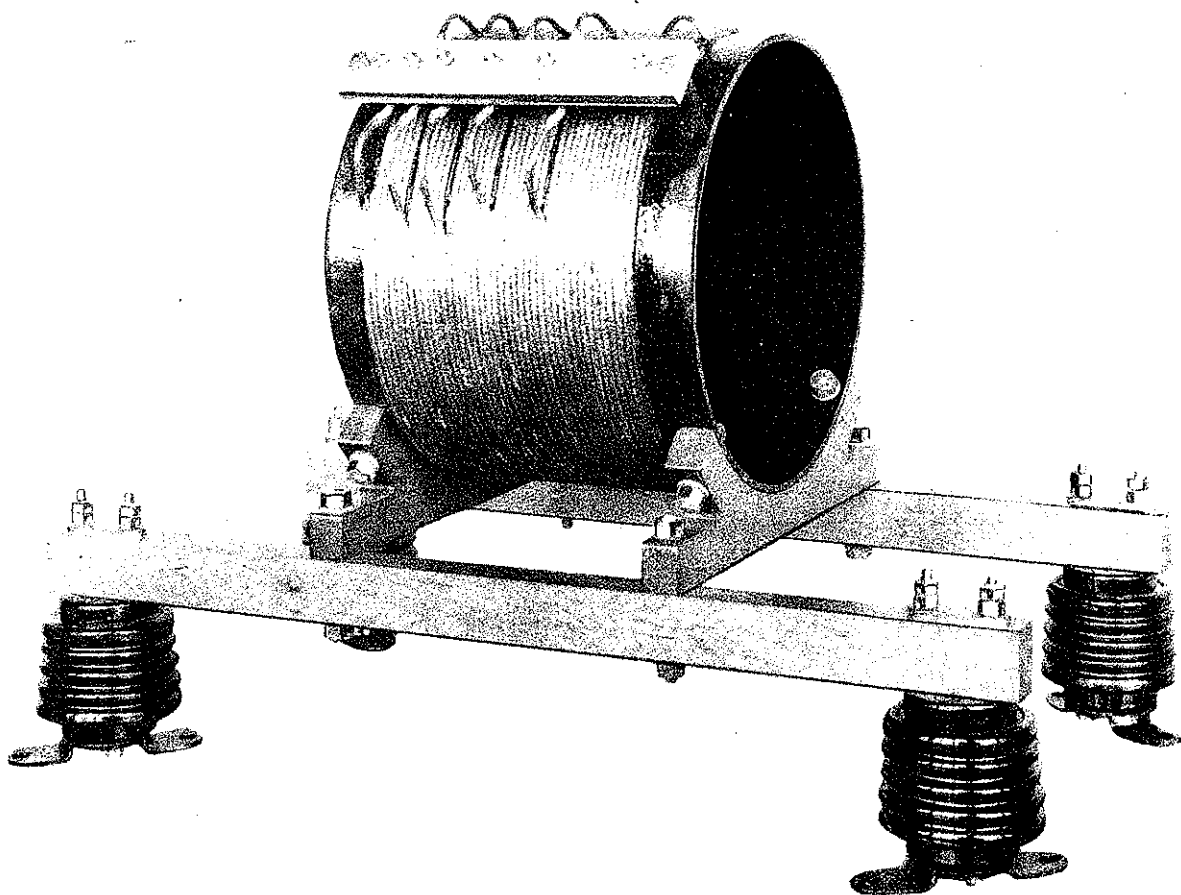


Figure 19

When the signal switch on the panel is placed in the ICW position the motor-driven chopper commutator M1 functions to break the grid leak circuit of the master oscillator and oscillation stops. The group frequency of the transmitted signal on ICW operation is approximately 800 cycles. The path of the oscillator grid current is through the radio frequency choke L10 and grid leak resistor R6. The excitation of the intermediate power amplifier grids from the output high-frequency of the master oscillator is through the by-pass condenser C7. The circuit is arranged so that whenever the chopper interrupts the oscillator grid, excitation of the amplifiers cease and the plate current of these tubes will drop to zero. The complete discontinuance of the plate current in the amplifiers minimizes the key clicks and this action is controlled automatically because a cut-off bias is supplied to the grids of the six amplifiers from a 125 volt d-c. bias generator. This generator operates in conjunction with the motor-generator unit and also supplies the direct current for the excitation of the plate generator field.

In order to minimize the radiation of very high-frequency harmonics the capacitance furnished by condenser C13, (shown shunted across the plate coil of the antenna coupling transformer T3), is used to by-pass harmonic energy.

The large radio power transferred from the two UV-851 tubes to the antenna through the coupling transformer T3 builds up the potential on the antenna

side of the loading inductance to values as high as 32,000 volts, and an antenna current of about 25 amperes may be expected.

EXAMINATION - LESSON 62

1. Draw a schematic diagram of a Meissner oscillator circuit.
2. Draw a simple diagram of a Colpitts oscillator.
3. Draw a simple diagram of a Hartley type oscillator.
4. State the essential difference between the Hartley and Colpitts oscillator circuits.
5. (a) Explain the purpose of the "seven-pole double-throw" switch on the panel of the E.T. 3626-B transmitter. (b) Why do oscillations stop when the sending key is in the "up" position? (c) What is the "audio oscillator" circuit used for and when is it brought into practical operation?
6. Give 10 steps for placing the E.T. 3626-B in and out of operation.
7. (a) Suppose you are operating the 3626-B and could not obtain radiation and you found the grid leak to be defective what would you proceed to do? (b) How could the set be operated in an emergency if the filament transformer burned out? (c) What do you think the usual indications would be if the proper grid bias was not maintained on the tubes? (d) How are ultra high-frequencies suppressed in the circuits? What other name is sometimes given to these unwanted oscillations?
8. (a) How many tubes are used in the E.T. 3627-A set and what is the name and purpose of each one? (b) What type oscillator circuit is used in this set? (c) What instrument is embodied in the design in order that the oscillator frequency can be quickly and accurately changed when desired? (d) Why is a "break-in" relay employed and, briefly, how does it function?
9. (a) Why do some of the commercial vacuum tube sets utilize a chopper? (b) If a chopper is not provided what special type of circuit would you expect to find incorporated in the design of the set? (c) What is the purpose of a power amplifier tube? How many are used in the E.T. 3626-B and how are they connected?
10. (a) In the E.T. 3638 transmitter how is the complete stopping of the plate current assured when the sending key is up and signals are not being sent out. (b) Name the different types of tubes used in this set and give their functions. (c) In what way does this set differ materially from either the E.T. 3626-B and E.T. 3627-A?